EOTA®

TECHNICAL REPORT

Design methods for anchorages with metal injection anchors and screw anchors for use in masonry

TR 054

April 2016

Amended April 2022

EUROPEAN ORGANISATION FOR TECHNICAL ASSESSMENT

WWW.EOTA.EU

Contents

1 SCOPE OF THE TECHNICAL REPORT

The design rules in this Technical Report (TR) are only valid for anchors with a European Technical Assessment (ETA) on basis of EAD 330076-00-0604 [1] or EAD 330076-01-0604 [6] or on basis of EAD 330460-00-0604 [7]. This document relies on characteristic resistances and distances which are stated in the ETA and referred to in this TR.

The design method applies to the design of injection and screw anchors in masonry units of clay, calcium silicate, normal weight concrete, light weight concrete, autoclaved aerated concrete (AAC) or other similar materials.

The proof of local transmission of the anchor loads into the masonry units is delivered by using the design methods described in this document. Proof of transmission of anchor loads to the supports of the masonry members shall be done by the engineer of the construction works.

The design and construction of masonry structures in which the injection and screw anchors are to be anchored shall be comparable with the structural rules for masonry, such as EN 1996 1-1:2005 + A1:2012 Clause 3 and 8 [6] and the relevant national regulations.

1.1 Type of anchors, anchor groups and number of anchors

The essential characteristics of the anchor (characteristic resistance values, edge distances, spacing and group factors) are given in the relevant ETA.

The design method is valid for single anchors and anchor groups with two or four anchors. In an anchor group only anchors of the same type, size and length shall be used.

1.2 Base material

The detailed information of the corresponding base material is given in the ETA.

Base materials are defined as follows:

- masonry material (clay, calcium silicate, normal weight concrete, lightweight aggregate concrete, autoclaved aerated concrete or other similar materials),
- the specific masonry units including size of units, geometry of holes, webs and shells,
- for masonry units: mean gross dry density and normalised mean compressive strength of the masonry unit and mean compressive strength,
- for joints unfilled with mortar: joint width,
- for joints filled with mortar: mortar class, joint width,
- consideration of plaster or similar materials,
- setting position (wall side or reveal, distance to joints).

1.3 Type and direction of load

This Technical report applies only to anchors subject to static or quasi-static actions in tension, shear or combined tension and shear or bending.

The anchors are also intended to be used in areas with very low seismicity as defined in EN 1998-1:2004 + AC:2009, Clause 3.2.1 [5]. This Technical report covers applications only where the masonry members in which the anchors are embedded are subject to static or quasi-static actions.

1.4 Specific terms used in this TR

Anchor	=	a manufactured, assembled component (in case of injection anchors including bonding materials) for achieving anchorage between the base material (masonry) and the fixture.
Anchor group	=	several anchors (working together)
Fixture	=	component to be fixed to the masonry
Anchorage	=	an assembly comprising base material (masonry), anchor or anchor group and component fixed to the masonry

Anchors

The notations and symbols frequently used in this TR are given below. Further particular notation and symbols are given in the text.

b_{brick}	=	breadth of the brick
c	=	edge distance towards the free edge of the brick
c_{cr}	=	edge distance for ensuring the transmission of the characteristic resistance of a single injection anchor /screw anchor
c_{min}	=	minimum edge distance to the free edge of the wall
c_j	=	edge distance to joints without influence on resistance of the screw
c_{jII}	=	distance to vertical joints without influence on resistance of the screw
$c_{j\perp}$	=	distance to horizontal joints without influence on resistance of the screw
$c_{j,fi}$	=	edge distance to joints without influence on resistance of the screw in case of fire exposure
d	=	anchor bolt/thread diameter
d_f	=	diameter of clearance hole in the fixture
d_{nom}	=	outside diameter of anchor
h	=	thickness of masonry member (wall)
h_{min}	=	minimum thickness of masonry member
h_{ef}	=	effective anchorage depth
h_{nom}	=	overall anchor embedment depth in the masonry
h_{brick}	=	h_{unit} = height of the brick
l_{brick}	=	l_{unit} = length of the brick
s	=	spacing of the injection anchor / screw anchor
s_{cr}	=	spacing for ensuring the transmission of the characteristic resistance of a single injection anchor / screw anchor
$s_{cr,II}$	=	s_{cr} parallel to the horizontal joint
$s_{cr,\perp}$	=	s_{cr} perpendicular to the horizontal joint
s_{min}	=	minimum allowable spacing
s_{minII}	=	minimum spacing parallel to the horizontal joint
$s_{min\perp}$	=	minimum spacing perpendicular to the horizontal joint
t_{fix}	=	thickness of fixture
w_j	=	maximum width of joints (for $c < c_j$)

Base materials (masonry) and metal parts of anchor

f_b	=	normalised mean compressive strength of masonry unit given in the ETA
f_{mean}	=	mean compressive strength of masonry (intended use) according to EN 772-1 [4]
f_{yk}	=	nominal characteristic steel yield strength
f_{uk}	=	nominal characteristic steel ultimate strength

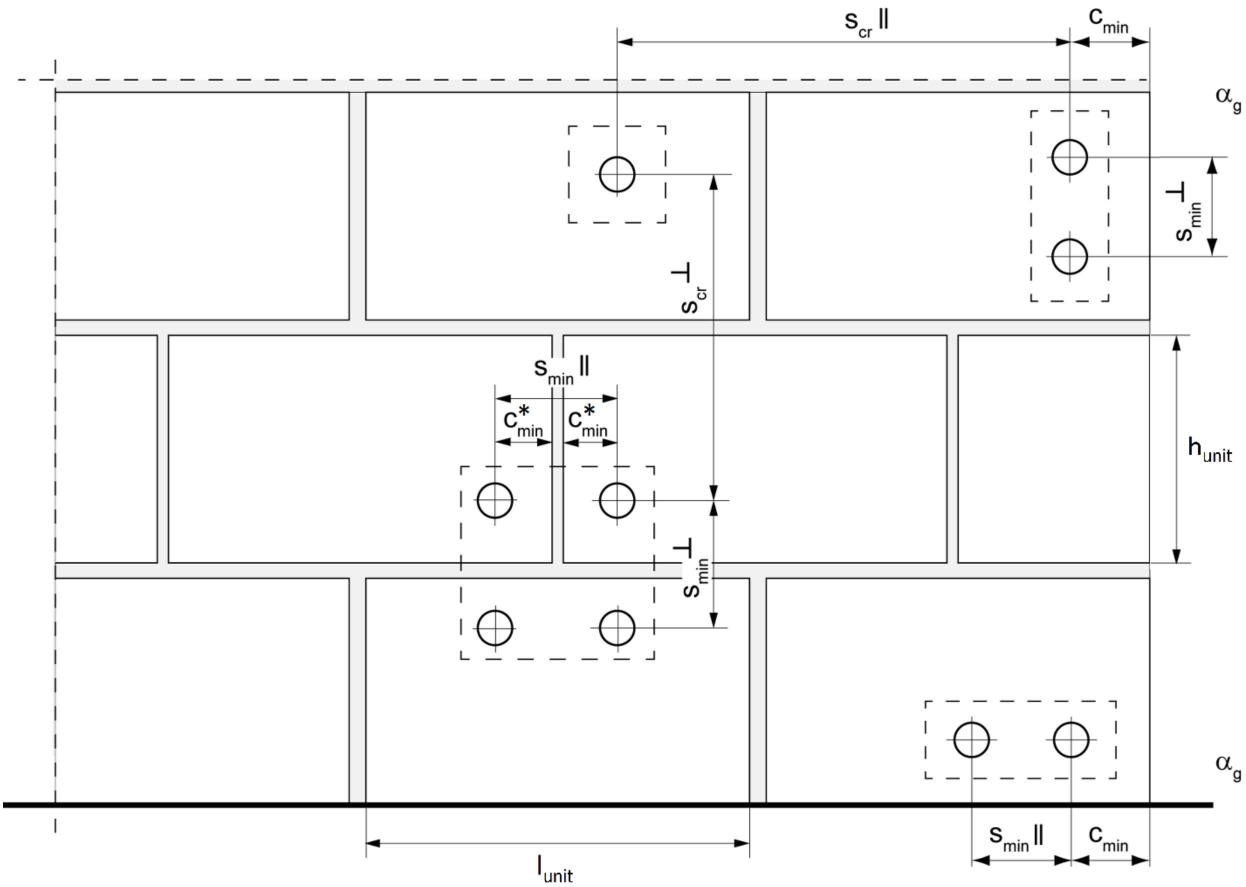
Loads / Forces / Resistances

F	=	force in general
N	=	normal force (+N = tension force)
V	=	shear force
M	=	moment
N_{Rk}, V_{Rk}	=	characteristic anchor resistance of a single anchor under tension or shear force
N_{Rk}^g, V_{Rk}^g	=	characteristic anchor resistance of an anchor group under tension or shear force
N_{Ed}^g, V_{Ed}^g	=	design value of actions acting on an anchor group
N_{Ed}^h, V_{Ed}^h	=	design value of actions acting on the highest loaded anchor
$a_{g,N}$	=	group factor under tension load

$\alpha_{g,V\parallel}$	=	group factor for screw groups under shear load parallel to the edge
$\alpha_{g,V\perp}$	=	group factor for screw groups under shear load perpendicular to the edge
$\alpha_{j,N}$	=	reduction factor for resistance under tension loading for-screws influenced by joints
$\alpha_{j,V\parallel}$	=	reduction factor for resistance under shear loading parallel to the vertical joint for-screws influenced by joints
$\alpha_{j,V\perp}$	=	reduction factor for resistance under shear loading perpendicular to the vertical joint for screws influenced by joints

Displacements

$d\ (d_N, d_V)$	=	displacement (movement) of the anchor at the masonry surface relative to the masonry surface in direction of the load (tension, shear) outside the failure area. The displacement includes the steel and masonry deformations and a possible anchor slip.
d_0	=	displacement of the anchor under short-term loading
d_∞	=	displacement of the anchor under long term loading



c_{min}^*	=	minimum edge distance, only if vertical joints are not filled with mortar

Figure 1.1: Edge distances, spacing for injection anchors

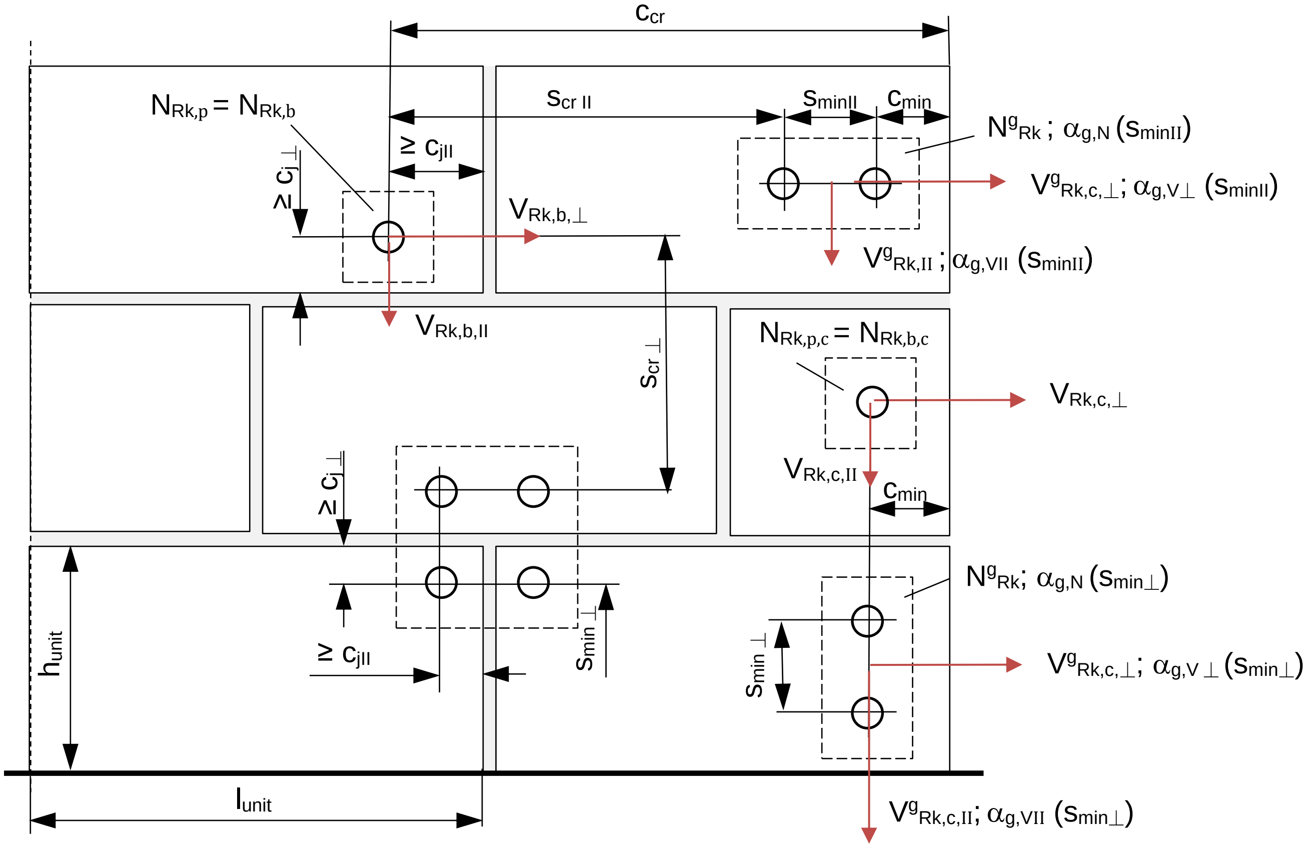


Figure 1.2: Edge distances, joint distances, spacing and resistances for screw anchors

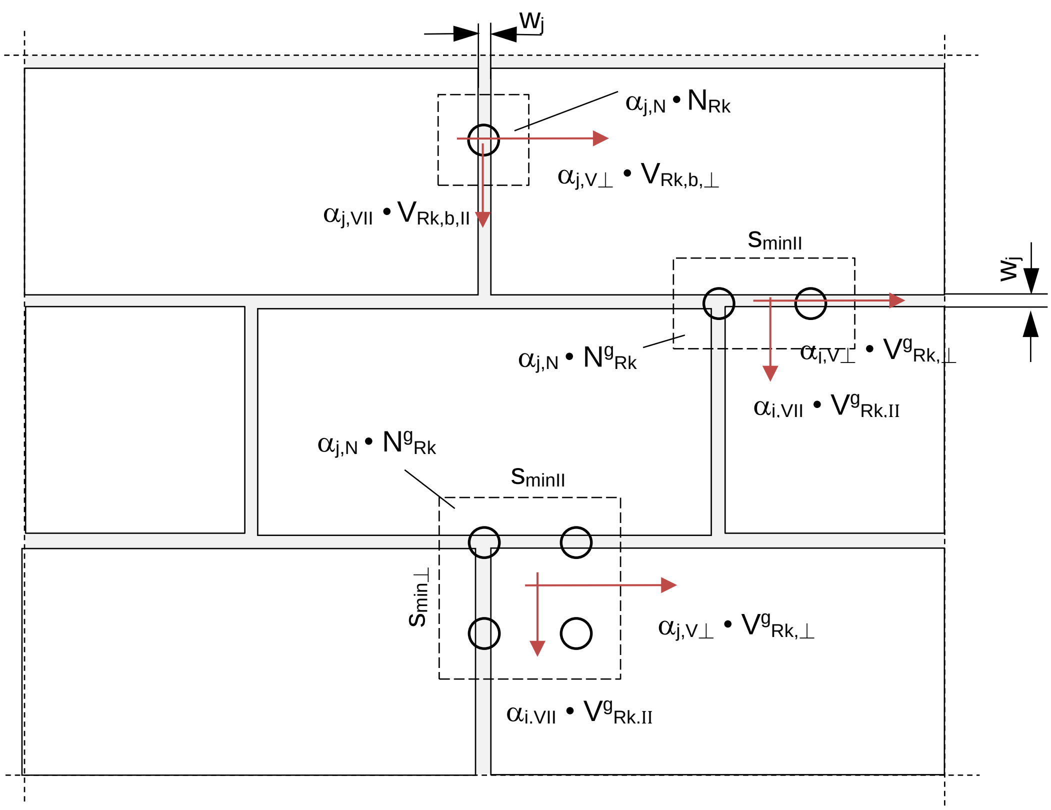


Figure 1.3: Reduction factors for resistances of screws in or near joints

2 DESIGN AND SAFETY CONCEPT

2.1 Design concept

The design of anchorages shall be in accordance with the general rules given in EN 1990 [2]. It shall be shown that the value of the design actions E_d does not exceed the value of the design resistance R_d.

$$E_d \leq R_d \tag{2.1}$$

with: E_d = design value of action
R_d = design value of resistance

Actions to be used in design may be obtained from national regulations or in the absence of them from the relevant parts of EN 1991 [3].

The partial safety factors for actions may be taken from national regulations or in the absence of them according to EN 1990 [2].

The design resistance is calculated as follows:

$$R_d = R_k/\gamma_M \tag{2.2}$$

with: R_k = characteristic resistance of a single anchor or an anchor group
γ_M = partial safety factor for material

2.2 Ultimate limit state

The design resistance is calculated according to Equation (2.2).

In absence of national regulations, the following partial safety factors may be used:

<u>Failure (rupture) of the metal part</u>

Tension loading:

$$\gamma_{Ms} = \frac{1{,}2}{f_{yk}/f_{uk}} \geq 1{,}4 \tag{2.3}$$

Shear loading of the anchor with and without lever arm:

$$\gamma_{Ms} = \frac{1{,}0}{f_{yk}/f_{uk}} \geq 1{,}25 \qquad f_{uk} \leq 800 \text{ N/mm}^2 \text{ and } \quad f_{yk}/f_{uk} \leq 0{,}8 \tag{2.4}$$

$$\gamma_{Ms} = 1{,}5 \qquad f_{uk} > 800 \text{ N/mm}^2 \text{ or } \quad f_{yk}/f_{uk} > 0{,}8$$

<u>Failure of the injection anchor or screw anchor</u>

For use in masonry: $\gamma_{Mm} = 2{,}5$

For use in autoclaved aerated concrete: $\gamma_{MAAC} = 2{,}0$

<u>Failure under fire exposure</u>

For all materials and all failure modes: $\gamma_{M,fi} = 1{,}0$

2.3 Serviceability limit state

In serviceability limit state it shall be shown that the displacements occurring under the characteristic actions (see chapter 6) are not larger than the permissible displacements. The permissible displacements depend on the application in question and shall be evaluated by the designer.

In this check the partial safety factors on actions and on resistances may be assumed to be equal 1,0.

3 STATIC ANALYSIS

3.1 Loads acting on anchors

Distribution of loads acting on anchors shall be calculated according to the theory of elasticity.

For steel failure under tension and shear and for pull-out failure under tension the load acting on the highest loaded anchor shall be determined.

In case of brick edge failure, the shear load is assumed to act on the anchor(s) closest to the edge.

3.2 Shear loads with or without lever arm

Shear loads acting on an anchor may be assumed to act without lever arm if all of the following conditions are fulfilled:

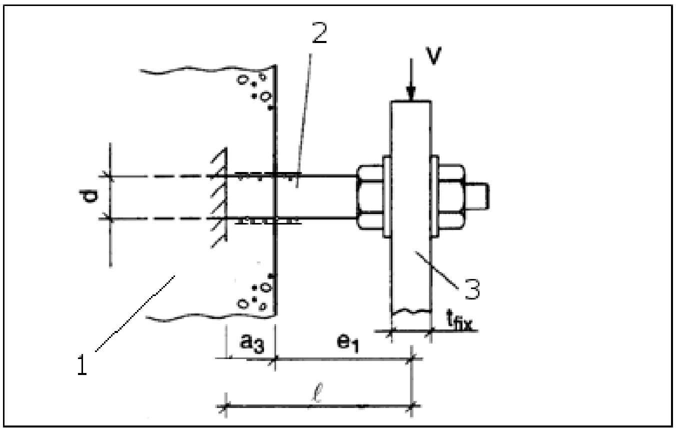
1. The fixture shall be made of metal and in the area of the anchorage be fixed directly to the base material without an intermediate layer or with a levelling layer of mortar with a compressive strength ≥ 30 N/mm² and a thickness ≤ $d/2$.
2. The fixture is in contact with the anchor over a length of at least 0,5 t_{fix}.
3. The diameter d_f of the hole in the fixture is not greater than the values d_f given in Table 3.1.

If these conditions are not fulfilled the bending moment acting on the anchor and the lever arm is calculated according to following Equation.

$$M_{Ed} = V_{Ed} \cdot \frac{l}{\alpha_M} \quad (3.1)$$

with:
- V_{Ed} = shear load acting on the anchor
- l = length of the lever arm (see also Figure 3.1)
  $l = a_3 + e_1$
- e_1 = distance between shear load and surface of the member
- a_3 = 0,5 · d
- d = diameter of the anchor bolt or thread diameter
- α_M = depends on the degree of restraint of the anchor at the side of the fixture of the application in question and shall be judged according to good engineering practice
  - $\alpha_M = 1{,}0$ No restraint is assumed if the fixture can rotate freely (see Figure 3.2a). This assumption is always conservative.
  - $\alpha_M = 2{,}0$ Full restraint may be assumed only if the fixture cannot rotate (see Figure 3.2b) and the hole clearance in the fixture is smaller than the values given in Table 3.1 or the anchor is clamped to the fixture by nut and washer (see Figure 3.1). If restraint of the anchor is assumed the fixture shall be able to take up the restraint moment.

Note: Equation (3.1) gives only information on the acting bending moment in principle. The verification is done with V_{Ed} and $V_{Rd,s,M}$ (see Equation (4.6)).



1 Masonry
2 Anchor bolt
3 Fixture

Figure 3.1: Definition of lever arm

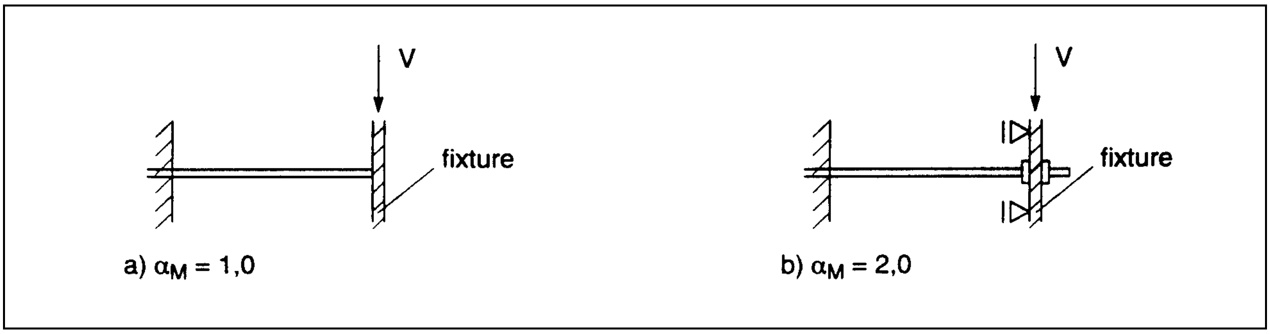


Figure 3.2: Fixture without (a) and with (b) restraint

Table 3.1: Diameter of clearance hole in the fixture

Outside anchor bolt or thread diameter d or d_{nom} (mm)	6	8	10	12	14	16	18	20	22	24	30
Diameter of clearance hole in the fixture d_f (mm)	7	9	12	14	16	18	20	22	24	26	33

4 ULTIMATE LIMIT STATE

4.1 General

Spacing, edge distance as well as thickness of member shall not remain under the given minimum values in the ETA.

4.2 Resistance to tension loads

4.2.1 Required proofs

Failure of the metal part	$N_{Ed}^{h} \leq N_{Rk,s}/\gamma_{Ms}$	4.2.2
Pull-out failure of the anchor	$N_{Ed}^{h} \leq N_{Rk,p}/\gamma_{Mm}$ $N_{Ed}^{h} \leq N_{Rk,p,c}/\gamma_{Mm}$	4.2.3
Brick breakout failure	$N_{Ed} \leq N_{Rk,b}/\gamma_{Mm}$ $N_{Ed} \leq N_{Rk,b,c}/\gamma_{Mm}$ $N_{Ed}^{g} \leq N_{Rk,b}^{g} / \gamma_{Mm}$	4.2.4
Pull out of one brick	$N_{Ed} \leq N_{Rk,pb}/\gamma_{Mm}$	4.2.5
Influence of joints	$N_{Ed}^{h} \leq \alpha_{j,N} N_{Rk,p}/\gamma_{Mm}$ $N_{Ed} \leq \alpha_{j,N} N_{Rk,b}/\gamma_{Mm}$ $N_{Ed}^{g} \leq \alpha_{j,N} N_{Rk,b}^{g} / \gamma_{Mm}$	4.2.6

For anchorages in AAC the partial safety factor γ_{MAAC} is to be used instead of γ_{Mm}.

4.2.2 Failure of the metal part

The characteristic resistance of an anchor in case of failure of the metal part $N_{Rk,s}$ is given in the relevant ETA. In case of no characteristic resistance is given in the ETA, the following equations may be applied.

$$N_{Rk,s} = A_s \cdot f_{uk} \quad (4.1)$$

with: A_s = decisive cross section of the anchor
f_{uk} = nominal characteristic steel ultimate strength

4.2.3 Pull-out failure of the anchor

The characteristic resistance in case of failure by pull-out of the anchor $N_{Rk,p}$ and $N_{Rk,p,c}$ and the corresponding values for spacing and edge distance $s_{cr,II}$, $s_{cr,\perp}$ and c_{cr} or c_{min} are given in the relevant ETA.

The corresponding distances of screw anchors to joints $c_{j,II}$ and $c_{j,\perp}$ are given in the relevant ETA.

4.2.4 Brick breakout failure

The characteristic resistance of one anchor in case of brick breakout failure $N_{Rk,b}$ and $N_{Rk,b,c}$ and the corresponding values for spacing and edge distance $s_{cr,II}$, $s_{cr,\perp}$ and c_{cr} or c_{min} are given in the relevant ETA.

The characteristic resistance of a group of two or four anchors $N_{Rk,b}^{g}$ and the corresponding values for spacing and edge distance $s_{min,II}$, $s_{min,\perp}$ and c_{min} are given in the relevant ETA.

The corresponding distances of screw anchors to joints c_{jII} and $c_{j\perp}$ are given in the relevant ETA.

Unless otherwise specified in the ETA, the characteristic resistance of a group with spacing smaller than s_{crII} and $s_{cr\perp}$ ($s_{min} \leq s \leq s_{cr}$) can be assumed to be at least the characteristic resistance of a corresponding single anchor.

4.2.5 Pull out of one brick

The characteristic resistance of an anchor or a group of anchors in case of pull out of one brick $N_{Rk,pb}$ is calculated as follows:

Vertical joints are not filled with mortar

$$N_{Rk,pb} = 2 \cdot l_{brick} \cdot b_{brick} \, (0{,}5 \cdot f_{vko} + 0{,}4 \cdot s_d) \tag{4.2}$$

Vertical joints are filled with mortar

$$N_{Rk,pb} = 2 \cdot l_{brick} \cdot b_{brick} \, (0{,}5 \cdot f_{vko} + 0{,}4 \cdot s_d) + 2 \cdot l_{brick} \cdot h_{brick} \cdot 0{,}5 \cdot f_{vko} \tag{4.3}$$

with: $N_{Rk,pb}$ = characteristic resistance for pull out of one brick
l_{brick} = length of the brick
b_{brick} = breadth of the brick
h_{brick} = height of the brick
s_d = minimum design compressive stress perpendicular to the shear
f_{vko} = initial shear strength according to EN 1996 1-1 [4], Table 3.4

Note: The factor 0,5 regarding f_{vko} considers the difference between the shear strength of a wall given in the EN 1996 1-1 [4], Table 3.4 and the shear strength of only one brick in case of pull out.

4.2.6 Influence of joints

The information on the consideration of joints is given in the corresponding ETA. If no information is given in the ETA, the following specification can be applied:

The characteristic resistance $N_{Rk,p}$, $N_{Rk,b}$ and $N_{Rk,b}^{g}$ for setting positions in bricks may be used if the joints of the masonry are completely filled with mortar.

Metal injection anchors:

If the joints of the masonry are not completely filled with mortar and the distance to the joint is $c \geq c_{min}^{*}$ then the characteristic resistances $N_{Rk,p,c}$, $N_{Rk,b,c}$ und $N_{Rk,b}^{g}$ may be used.

If the joints of the masonry are not completely filled with mortar and the minimum edge distance to the joint is $c \geq c_{min}^{*}$ then the characteristic resistance $N_{Rk,p}$, $N_{Rk,b}$ und $N_{Rk,b}^{g}$ has to be reduced by the factor $\alpha_{j,N}$ = 0,75.

Screw anchors:

The characteristic resistances $N_{Rk,p,c}$, $N_{Rk,b,c}$ and $N_{Rk,b}^{g}$ may be used only if the distance to the joint is $c \geq c_j$.

If the width of joints is smaller or equal to w_j (given in the ETA) and the distance to the joint is $c < c_j$ then the characteristic resistances $N_{Rk,p}$, $N_{Rk,b}$ and $N_{Rk,b}^{g}$ have to be reduced by the factor $\alpha_{j,N}$ given in the ETA.

4.3 Resistance to shear loads

4.3.1 Required proofs

Failure of the metal part, shear load without lever arm	$V_{Ed}^{h} \leq V_{Rk,s}/\gamma_{Ms}$	4.3.2
Failure of the metal part, shear load with lever arm	$V_{Ed}^{h} \leq V_{Rk,s,M}/\gamma_{Ms}$	4.3.3
Local brick failure	$V_{Ed} \leq V_{Rk,b}/\gamma_{Mm}$ $V_{Ed}^{g} \leq V_{Rk,b}^{g} / \gamma_{Mm}$	4.3.4
Brick edge failure	$V_{Ed} \leq V_{Rk,c}/\gamma_{Mm}$ $V_{Ed}^{g} \leq V_{Rk,c}^{g} / \gamma_{Mm}$	4.3.5
Pushing out of one brick	$V_{Ed} \leq V_{Rk,pb}/\gamma_{Mm}$	4.3.6
Influence of joints	$V_{Ed} \leq \alpha_{j,V} V_{Rk,b}/\gamma_{Mm}$ $V_{Ed}^{g} \leq \alpha_{j,V} V_{Rk,b}^{g} / \gamma_{Mm}$	4.3.7

For anchorages in AAC the partial safety factor γ_{MAAC} is to be used instead of γ_{Mm}.

4.3.2 Failure of the metal part, shear load without lever arm

The characteristic resistance of an anchor in case of failure of the metal part due to shear load without lever arm $V_{Rk,s}$ shall be taken from the relevant ETA.

In case of no characteristic resistance is given in the ETA, the following Equation may be applied.

$$V_{Rk,s} = 0{,}5 \cdot A_s \cdot f_{uk} \tag{4.5}$$

with: A_s = decisive cross section of the anchor
f_{uk} = nominal characteristic steel ultimate strength

4.3.3 Failure of the metal part, shear load with lever arm

The characteristic resistance of an anchor in case of failure of the metal part due to shear load with lever arm $V_{Rk,s,M}$ is given by following Equation:

$$V_{Rk,s,M} = \frac{\alpha_M \cdot M_{Rk,s}}{l} \tag{4.6}$$

with: l = lever arm according to Equation (3.1)
α_M = depends on the degree of restraint of the anchor at the side of the fixture of the application, see Equation (3.1)
$M_{Rk,s}$ = $M_{Rk,s}^{0} \left(1 - \frac{N_{Ed}}{N_{Rd,s}}\right)$
$M_{Rk,s}^{0}$ = taken from the relevant ETA
N_{Ed} = design value of actions under tension load
$N_{Rd,s}$ = design value of resistance to steel failure of the anchor under tension load

4.3.4 Local brick failure

The characteristic resistance of one anchor in case of local brick failure $V_{Rk,b}$ and the corresponding values for spacing and edge distance s_{crII}, $s_{cr\perp}$ and c_{cr} or c_{min} are given in the relevant ETA.

The characteristic resistance of a group of two or four injection anchors $V_{Rk,b}^{g}$ and the corresponding values for spacing and edge distance s_{minII}, $s_{min\perp}$ and c_{min} are given in the relevant ETA.

Unless otherwise specified in the ETA, the characteristic resistance of a group with spacing smaller than s_{crII} and $s_{cr\perp}$ ($s_{min} \leq s \leq s_{cr}$) can be assumed to be at least the characteristic resistance of a corresponding single anchor.

4.3.5 Brick edge failure

For anchors where the shear load acts with lever arm, the provisions are valid if $c > \max(10\ h_{ef}\ ; 60\ d)$. where c is the distance to the free edge of the wall or the distance to vertical joints not to be filled with mortar and the load acts perpendicular to the free edge.

NOTE In case of fastenings located close to an edge and loaded by a shear load with lever arm the effect of an overturning moment on the brick edge resistance is not considered in the following provisions.

The characteristic resistance for an anchor in the case of brick edge failure $V_{Rk,c}$ and the corresponding values for spacing and edge distance s_{crII}, $s_{cr\perp}$ and c_{cr} or c_{min} are given in the relevant ETA.

In case no characteristic resistance is given in the ETA, the following equations may be applied.

For anchorages in solid masonry and AAC the following determination may be used:

$$V_{Rk,c} = k \cdot \sqrt{d_{nom}} \cdot (h_{nom}/d_{nom})^{0,2} \cdot \sqrt{f_b} \cdot c^{1,5} \quad (4.7)$$

with: k = 0,25 if load direction is to the free edge
= 0,45 if load direction is parallel to the free edge

c = edge distance closest to the edge in mm

$c \geq c_{min}$

If the load is directed to the free edge and the wall is not designed such that the joints are filled with mortar (so no load transfer to other units in the wall is given) then the following conditions shall be fulfilled:

$c \leq h$ / 1,5

$c \leq h_{brick}$ / 3

d_{nom} = outside diameter of the anchor in mm

h_{nom} = overall anchor embedment depth in mm

f_b = normalized mean compressive strength of masonry unit in N/mm²

For anchorages in hollow or perforated masonry the following values correspond to current experience and no further determination is required:

$V_{Rk,c}$ = 2,50 kN if load direction is parallel to the free edge with $c \geq 100$ mm and $c \geq 6\ d_0$ and
if load direction is to the free edge with $c \geq 250$ mm

$V_{Rk,c}$ = 1,25 kN if load direction is to the free edge with $c \geq 100$ mm and $c \geq 6\ d_0$

Intermediate values can be interpolated.

The characteristic resistance of a group of two or four injection anchors $V_{Rk,c}^{g}$ and the corresponding values for spacing and edge distance s_{minII}, $s_{min\perp}$ and c_{min} are given in the relevant ETA. On the safe side the characteristic resistance of a group with spacing smaller than s_{crII} and $s_{cr\perp}$ ($s_{min} \leq s \leq s_{cr}$) can be assumed to be at least the characteristic resistance of a corresponding single anchor.

4.3.6 Pushing out of one brick

The characteristic resistance of an anchor or a group of anchors in case of pushing out of one brick on the free edge of a wall $V_{Rk,pb}$ is calculated as follows:

$$V_{Rk,pb} = 2 \cdot l_{brick} \cdot b_{brick}\ (0,5 \cdot f_{vko} + 0,4 \cdot s_d) \quad (4.8)$$

with: $V_{Rk,pb}$ = characteristic resistance for pull out of one brick

l_{brick} = length of the brick

b_{brick} = breadth of the brick

h_{brick} = height of the brick

s_d = minimum design compressive stress perpendicular to the shear

f_{vko} = initial shear strength according to EN 1996 1-1 [4], Table 3.4

4.3.7 Influence of joints

The information on the consideration of joints is given in the corresponding ETA. If no information is given in the ETA, the following specification can be applied:

The characteristic resistance $V_{Rk,b}$, $V_{Rk,c}$, $V_{Rk,b}^{g}$ and $V_{Rk,c}^{g}$ for setting positions in bricks may be used if the joints of the masonry are completely filled with mortar.

Metal injection anchors:

If the joints of the masonry are not completely filled with mortar then the joints have to be considered as a free edge and the minimum edge distance to the joint has to be $c \geq c_{min}^{*}$.

Screw anchors:

The characteristic resistances $V_{Rk,b}$, and $V_{Rk,b}^{g}$ may be used only if the distance to the joint is $c \geq c_j$.

If the width of joints is smaller or equal to w_j (given in the ETA) and the distance to the joint is $c < c_j$ then the characteristic resistances $V_{Rk,b}$ and $V_{Rk,b}^{g}$ have to be reduced by the factor $\alpha_{j,V}$ given in the ETA.

4.4 Resistance to combined tension and shear loads

For combined tension and shear loads the following equations shall be satisfied:

$b_N \leq 1{,}0$ (4.9)

$b_V \leq 1{,}0$ (4.10)

$b_N + b_V \leq 1{,}2$ for solid masonry (4.11)

$b_N + b_V \leq 1{,}0$ for perforated or hollow masonry for injection anchors (4.12)

$b_N + b_V \leq X$ for perforated or hollow masonry for screw anchors (4.13)

with: b_N (b_V) = ratio between design action and design resistance for tension (shear) loading. In Equations (4.9) to (4.12) the largest value of b_N and b_V for the different failure modes shall be taken (see 4.2.1 and 4.3.1).

X according to ETA of the screw anchor

4.5 Additional provisions for prefabricated reinforced components made of autoclaved aerated concrete

For prefabricated reinforced components made of autoclaved aerated concrete the following has to be taken into account as well, if no special tests or calculation for the resistance of the member made of autoclaved aerated concrete have been carried out:

The design value of shear resistance in the member caused by the anchorage is less than or equal to 40 % of the design value of resistance of the member in the critical cross section.

The edge distance c is ≥ 150 mm for slabs of width ≤ 700 mm.

The spacing of fixing points in general is a ≥ 250 mm. For prefabricated reinforced components of autoclaved aerated concrete the spacing of fixing points is a ≥ 600 mm. Fixing points are single anchors or groups of 2 or 4 anchors.

5 VERIFICATION FOR FIRE RESISTANCE

5.1 General

The fire resistance (stated in the ETA) is classified according to EN 13501-2 [8] using the Standard ISO time-temperature curve (STC).

The determination covers anchors with a fire attack from one side only. If the fire attack is from more than one side, the design method may be taken only, if the edge distance of the anchor to the free edge is $c \geq 300\,mm$ and $c \geq 2\,h_{ef}$ (for injection anchors) or $c \geq 2\,h_{nom}$ (for screw anchors).

The required spacing $s_{\min,fi}$ and edge distance $c_{\min,fi}$ for anchorages under fire exposure are given in the relevant ETA.

5.2 Resistance to tension loads

5.2.1 Required proofs

Failure of the metal part	$N^h_{Ed,fi} \leq N_{Rk,s,fi}/\gamma_{M,fi}$	5.2.2
Pull-out failure of the anchor	$N^h_{Ed,fi} \leq N_{Rk,p,fi}/\gamma_{M,fi}$	5.2.3
Brick breakout failure	$N_{Ed,fi} \leq N_{Rk,b,fi}/\gamma_{M,fi}$ $N^g_{Ed,fi} \leq N^g_{Rk,b,fi}\,/\,\gamma_{M,fi}$	5.2.4
Pull out of one brick	$N_{Ed,fi} \leq N_{Rk,pb,fi}/\gamma_{M,fi}$	5.2.5
Influence of joints		5.2.6

5.2.2 Resistance to steel failure

The characteristic resistance of an anchor in case of failure of the metal part $N_{Rk,s,fi}$ is given in the relevant ETA.

5.2.3 Pull-out failure

Metal injection anchors:

The characteristic resistance in case of failure by pull-out of the anchor $N_{Rk,p,fi}$ and the corresponding edge distances $c_{min,fi}$ shall be taken from the relevant ETA.

Screw anchors:

The characteristic resistance in case of failure by pull-out of the anchor $N_{Rk,p,fi}$ and the corresponding edge distances and joint distances $c_{min,fi}$, $c_{j,fi}$, are given in the relevant ETA.

5.2.4 Brick break out failure

Metal injection anchors:

The characteristic resistance in case of failure by pull-out of the anchor $N_{Rk,b,fi}$ and the corresponding edge distances and spacings $c_{min,fi}$ and $s_{min,fi}$ shall be taken from the relevant ETA.

Screw anchors:

The characteristic resistance in case of failure by brick break out of the anchor $N_{Rk,b,fi}$ and $N^g_{Rk,b,fi}$ and the corresponding edge distances, joint distances and spacings $c_{min,fi}$, $c_{j,fi}$, $s_{min,fi}$ are given in the relevant ETA.

5.2.5 Pull-out of one brick

Vertical joints are not filled with mortar

$$N_{Rk,pb,fi} = 2 \cdot l_{brick} \cdot (b_{brick} - t_{ineff}) \cdot (0{,}5 \cdot f_{vko} + 0{,}4 \cdot s_d) \quad (5.1)$$

Vertical joints are filled with mortar

$$N_{Rk,pb,fi} = 2 \cdot l_{brick} \cdot (b_{brick} - t_{ineff}) \cdot (0{,}5 \cdot f_{vko} + 0{,}4 \cdot s_d) + 2 \cdot l_{brick} \cdot h_{brick} \cdot 0{,}5 \cdot f_{vko} \quad (5.2)$$

with: $N_{Rk,pb,fi}$ = characteristic resistance for pull out of one brick under fire exposure

t_{ineff} = ineffective thickness of mortar in joints under fire exposure

$t_{ineff,fi,30}$ = 50 mm

$t_{ineff,fi,60}$ = 80 mm

$t_{ineff,fi,90}$ = 100 mm

l_{brick}, b_{brick}, h_{brick}, s_d, f_{vko} see Equation (4.3)

5.2.6 Influence of joints

The information on the consideration of joints is given in the corresponding ETA. If no information is given in the ETA, the following specification can be applied:

The characteristic resistance $N_{Rk,p,fi}$, $N_{Rk,b,fi}$ for setting positions in bricks may be used only if the joints of the masonry are completely filled with mortar.

Screw anchors

The distance to joints has to be $c \geq c_{j,fi}$.

5.3 Resistance to shear loads

5.3.1 Required proofs

Failure of the metal part, shear load without lever arm	$V_{Ed,fi} \leq V_{Rk,s,fi}/\gamma_{M,fi}$	5.3.2
Failure of the metal part, shear load with lever arm	$V_{Ed,fi} \leq V_{Rk,s,M,fi}/\gamma_{M,fi}$	5.3.3
Local brick failure	$V_{Ed,fi} \leq V_{Rk,b,fi}/\gamma_{M,fi}$ $V_{Ed,fi}^{g} \leq V_{Rk,b,fi}^{g} / \gamma_{M,fi}$	5.3.4
Pushing out of one brick	$V_{Ed,fi} \leq V_{Rk,pb,fi}/\gamma_{M,fi}$	5.3.5
Influence of joints		5.3.6

5.3.2 Failure of the metal part, shear load without lever arm

The characteristic resistance of an anchor in case of failure of the metal part $V_{Rk,s,fi}$ is given in the relevant ETA.

5.3.3 Failure of the metal part, shear load with lever arm

The characteristic resistance of an anchor in case of failure of the metal part $M_{Rk,s,fi}^{0}$ is given in the relevant ETA.

The characteristic resistance of an anchor in case of failure of the metal part due to shear load with lever arm $V_{Rk,s,M,fi}$ is given by following Equation:

$$V_{Rk,s,M,fi} = \frac{\alpha_M \cdot M_{Rk,s,fi}}{l} \quad (5.3)$$

with: l = lever arm according to Equation (3.1)

α_M = depends on the degree of restraint of the anchor at the side of the fixture of the application, see Equation (3.1)

$M_{Rk,s,fi}$ = $M^0_{Rk,s,fi}\,(1 - \frac{N_{Ed}}{N_{Rd,s}})$

$M^0_{Rk,s,fi}$ = taken from the relevant ETA

N_{Ed} = design value of actions under tension load in case of fire

$N_{Rd,s}$ = design value of resistance to steel failure of the anchor under tension load in case of fire

5.3.4 Local brick failure

The characteristic resistance in case of local brick failure under fire exposure may be obtained according to following equations:

$$V_{Rk,b,fi} = N_{Rk,b,fi} \tag{5.4}$$

$$V^g_{Rk,b,fi} = N^g_{Rk,b,fi} \tag{5.5}$$

with: $N_{Rk,b,fi}$ = shall be taken from the relevant ETA

$N^g_{Rk,b,fi}$ = given in the relevant ETA

5.3.5 Pushing out of one brick

The characteristic resistance of an anchor or a group of anchors in case of pushing out of one brick on the free edge of a wall $V_{Rk,pb,fi}$ is calculated as follows:

$$V_{Rk,pb,fi} = 2 \cdot l_{brick} \cdot (b_{brick} - t_{ineff}) \cdot (0{,}5 \cdot f_{vko} + 0{,}4 \cdot s_d) \tag{5.6}$$

with: $V_{Rk,pb,fi}$ = characteristic resistance for pull out of one brick under fire exposure

t_{ineff} = ineffective thickness of mortar in joints under fire exposure

$t_{ineff,fi,30}$ = 50 mm

$t_{ineff,fi,60}$ = 80 mm

$t_{ineff,fi,90}$ = 100 mm

l_{brick}, b_{brick}, h_{brick}, s_d, f_{vko} see Equation (4.8)

5.3.6 Influence of joints

The information on the consideration of joints is given in the corresponding ETA. If no information is given in the ETA, the following specification can be applied:

The characteristic resistance $V_{Rk,b,fi}$ for setting positions in bricks may be used if the joints of the masonry are completely filled with mortar.

Screw anchors

The distance to the joint has to be $c \geq c_{j,fi}$.

5.4 Resistance to combined tension and shear loads

The interaction condition according to normal temperature according to 4.4 may be taken with the characteristic resistance under fire exposure for the different loading directions for combined tension and shear loads.

6 SERVICEABILITY LIMIT STATE

6.1 Displacements

The characteristic displacement of the anchor under defined tension loads (d_{N0}; $d_{N\infty}$) and shear loads (d_{V0}; $d_{V\infty}$) shall be taken from the ETA. It may be assumed that the displacements are a linear function of the applied load. In case of a combined tension and shear load, the displacements for the tension and shear component of the resultant load shall be geometrically added.

In case of shear loads the influence of the hole clearance in the fixture on the expected displacement of the whole anchorage shall be taken into account.

6.2 Shear load with changing sign

If the shear loads acting on the anchor change their sign several times, appropriate measures shall be taken to avoid a fatigue failure of the anchor (e.g. the shear load shall be transferred by friction between the fixture and the base material (e.g. due to a sufficiently high permanent pre-stressing force).

Shear loads with changing sign can occur due to temperature variations in the fastened member (e.g. facade elements). Therefore, either these members are anchored such that no significant shear loads due to the restraint of deformations imposed to the fastened element will occur in the anchor or in shear loading with lever arm the bending stresses in the most stressed anchor $\Delta\sigma$ = $max s$ - $min s$ in the serviceability limit state caused by temperature variations shall be limited to 100 N/mm^2 for steel.

7 REFERENCE DOCUMENTS

[1] EAD 330076-00-0604: Metal injection anchors for use in masonry, April 2016

[2] EN 1990:2002 + A1:2005 / AC:2010: Eurocode: Basis of structural design

[3] EN 1991:2002 + AC 2009: Actions on structures

[4] EN 1996-1-1:2005 + A1:2012: Design of masonry structures. Part 1-1: General rules for reinforced and unreinforced masonry structure

[5] EN 1998-1:2004 + AC:2009: Eurocode 8: Design of structures for earthquake resistance – Part 1: General rules, seismic actions and rules for buildings

[6] EAD 330076-01-0604:2021-05: Metal injection anchors for use in masonry

[7] EAD 330460-00-0604:2020-09:Screw anchors for use in masonry

[8] EN 13501-2:2016: Fire classification of construction products and building elements – Part 2: Classification using data from fire resistance tests, excluding ventilation services